Landing and takeoff (LTO) noise aspects of supersonic flight

NAE Workshop: Advances in Noise Control Technology

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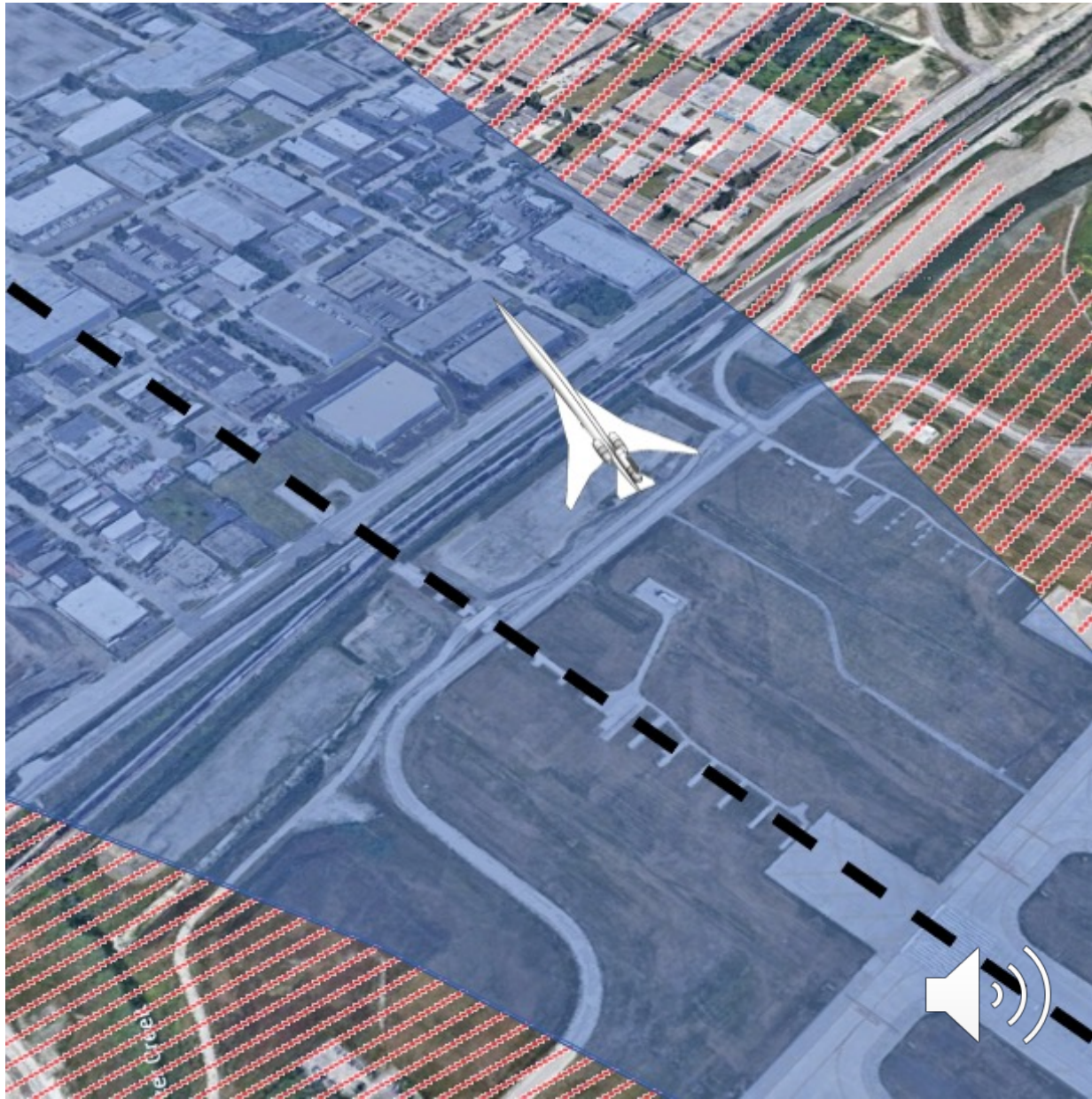
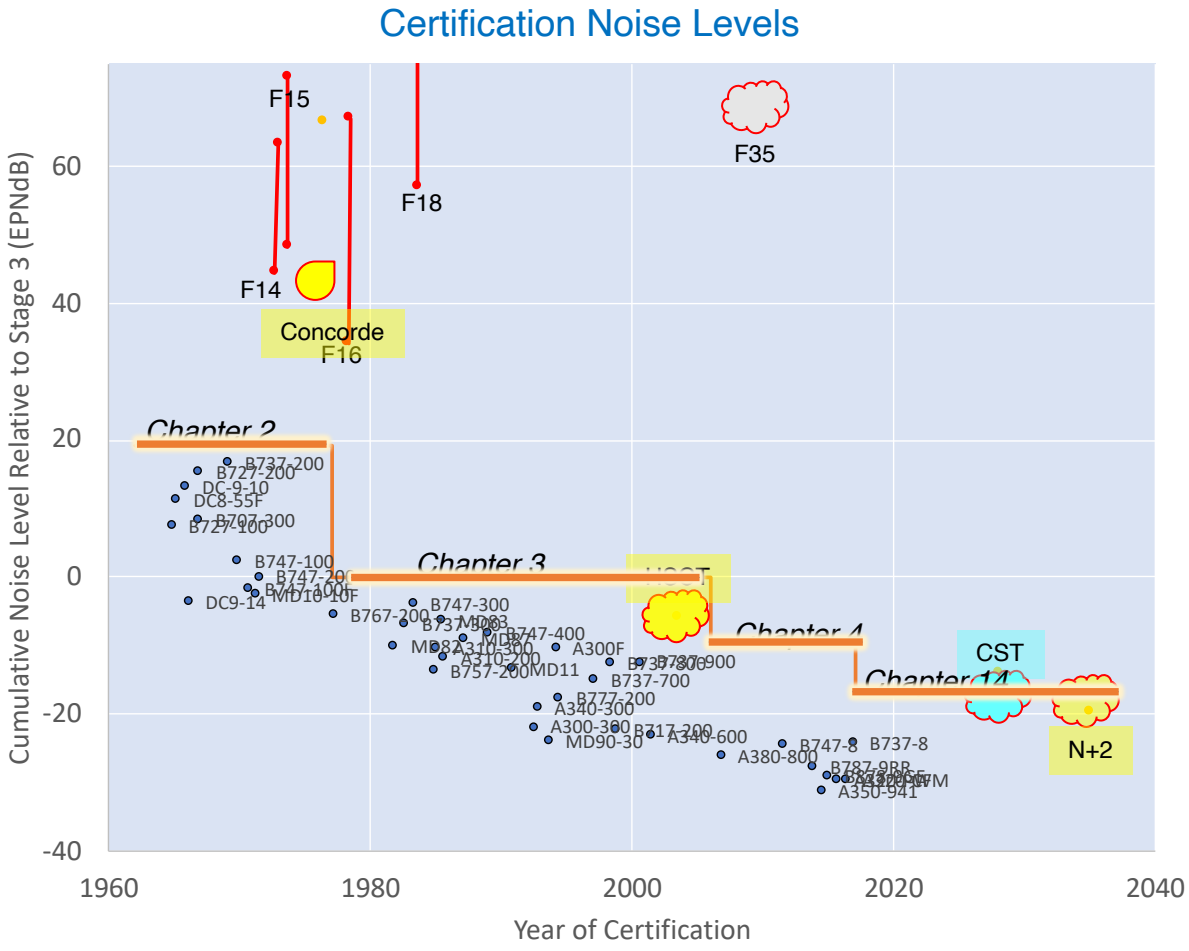


Concorde, HSCT, and Beyond

- Concorde (1960s tech)
  - Cruise Mach = 2, 100 pax, MGWT=185tonne
  - Four afterburning turbojet engines
  - Approximately 70 EPNdB (cum) louder than 1980 regulations. All jet noise.
  - **Not applicable to today's market.**
- NASA High Speed Civil Transport (1990s tech)
  - Cruise Mach = 2.4, 300 pax, MGWT=340tonne, BPR<1
  - Projected under Chapter 3 at great inefficiency.
  - **Technology not applicable to today's market.**
- NASA Supersonics Project's N+2/N+3 studies (2010-16)
  - Low-boom airliners (70+ pax), cruise Mach < 2, variable cycle (BPR>3)
  - Predicted to meet subsonic LTO noise regulations.
  - **Validated promising low TRL propulsion concepts for 2030+**
- NASA Commercial Supersonic Technology Project (2017-)
  - Near-term, 10 pax, cruise Mach < 1.6, existing propulsion technology
  - Noise predicted comparable to current commercial fleet.
  - **Technology available today. Noise less known.**



Noise prediction technology for Supersonics not as mature as Aero technology

The Problem

No certification noise rule for commercial supersonic aircraft.

- Regulatory Catch-22:
  - OEMs have no international noise rule for product requirements.
  - Regulators have no existing product for technical feasibility assessment.

- FAA has led with issuance of 'Notice of Proposed Rule-Making' (NPRM)
  - Technical assessment influenced by NASA system studies (noise predictions).
  - Further progress requires international collaboration.

- Technical committees need **reliable** noise predictions to assess **environmental** impacts against economic benefits
  - Must agree on the data before you can agree on the regulation.

April 2020: FAA issues NPRM for commercial supersonic transports

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Parts 21 and 36

[Docket No.: FAA–2020–0316; Notice No. 20–06]

RIN 2120–AL29

Noise Certification of Supersonic Airplanes

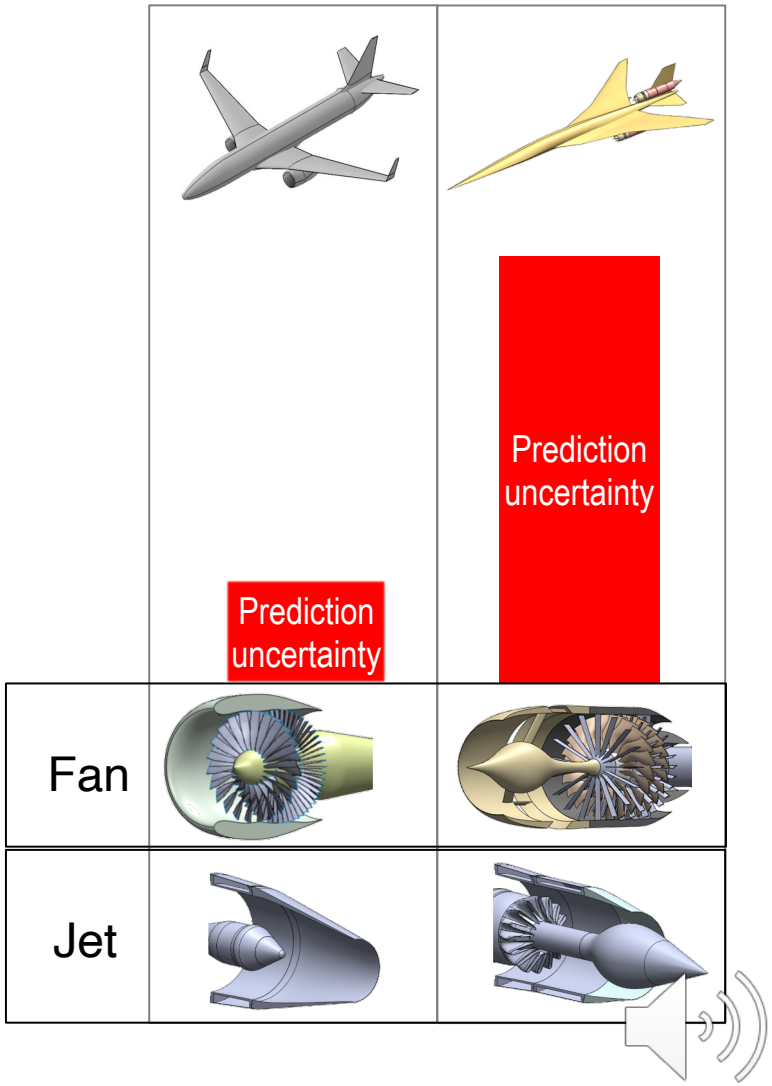
AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed rulemaking (NPRM).

The toughest question in technology: "How good is your number?"

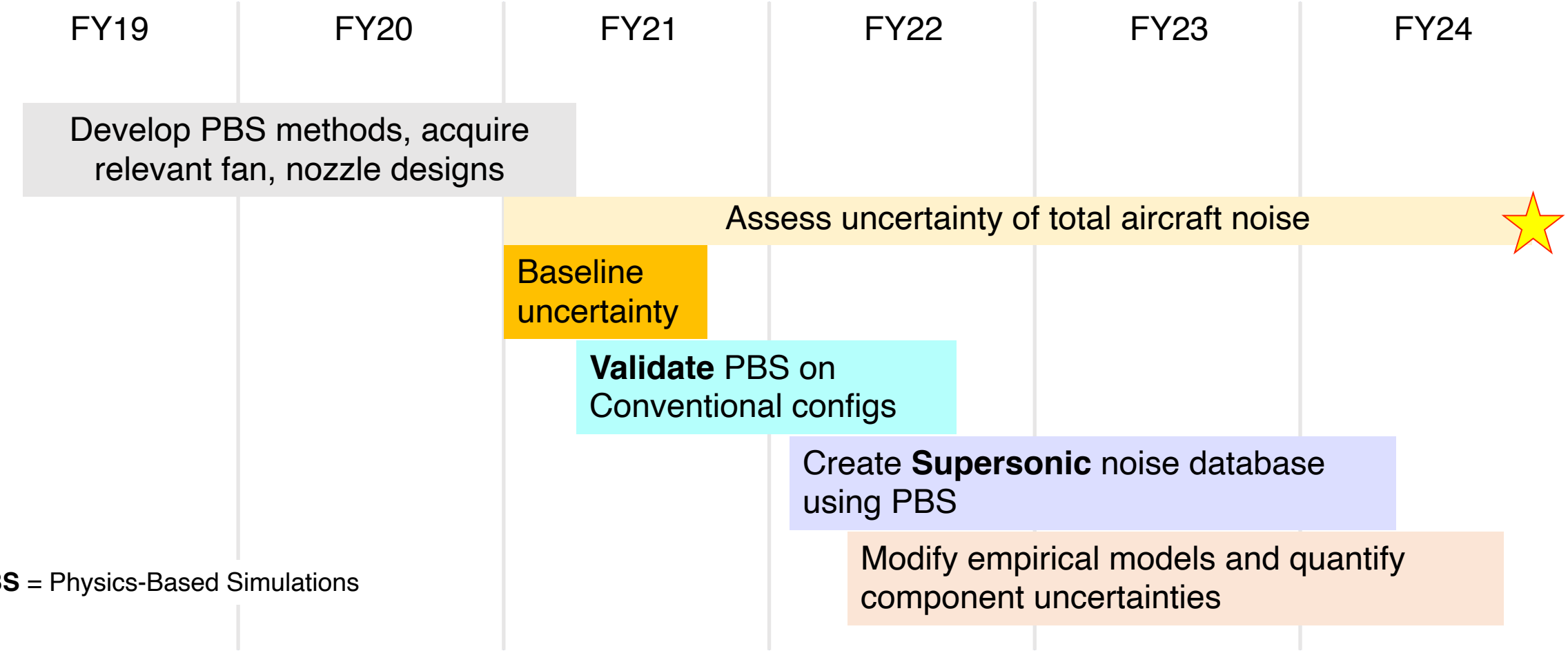
New Tech Challenge: Prediction Uncertainty Reduction

- Uncertainty in prediction of LTO noise is primarily associated with **configuration differences** between conventional and supersonic aircraft.
- Empirical prediction models only work if based on **relevant** data.
- Historical approach
  - High-fidelity scale **rig tests** of relevant supersonic configurations.
  - Construct empirical models from **experimental databases**.
- Tech Challenge approach
  - Use **physics-based simulations** (PBS) of supersonic aircraft to produce ‘data’.



Technical Approach

Tech Challenge Timeline

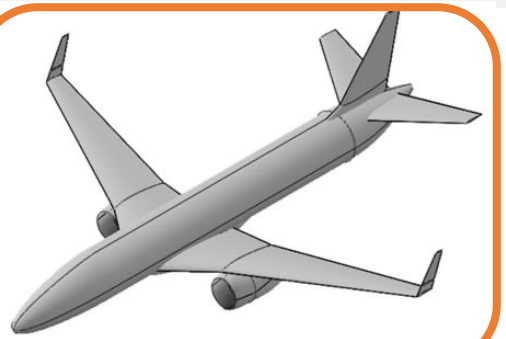
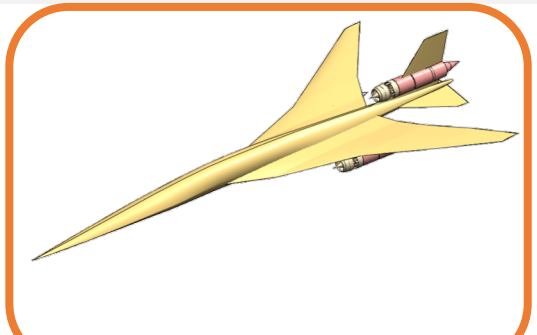


PBS = Physics-Based Simulations

Planned Activities

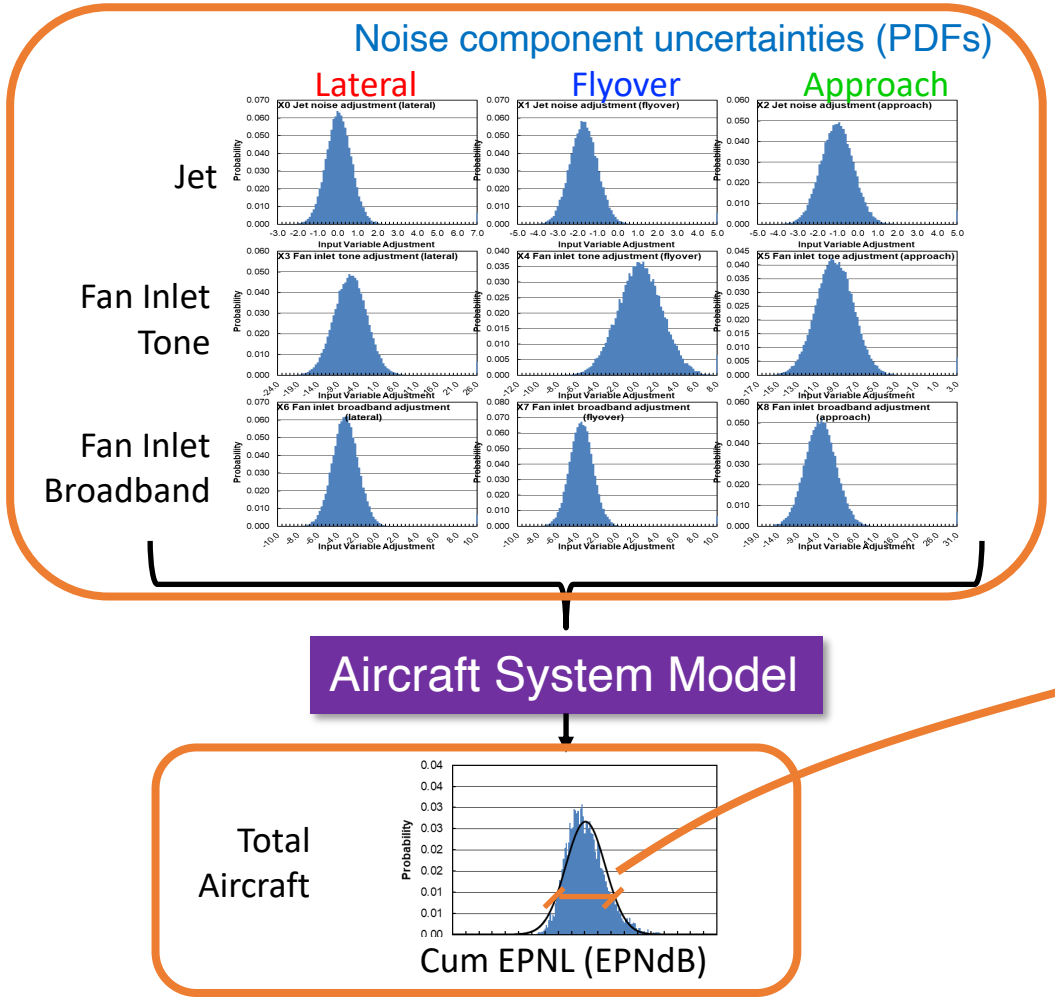
Baseline Uncertainty Assessment

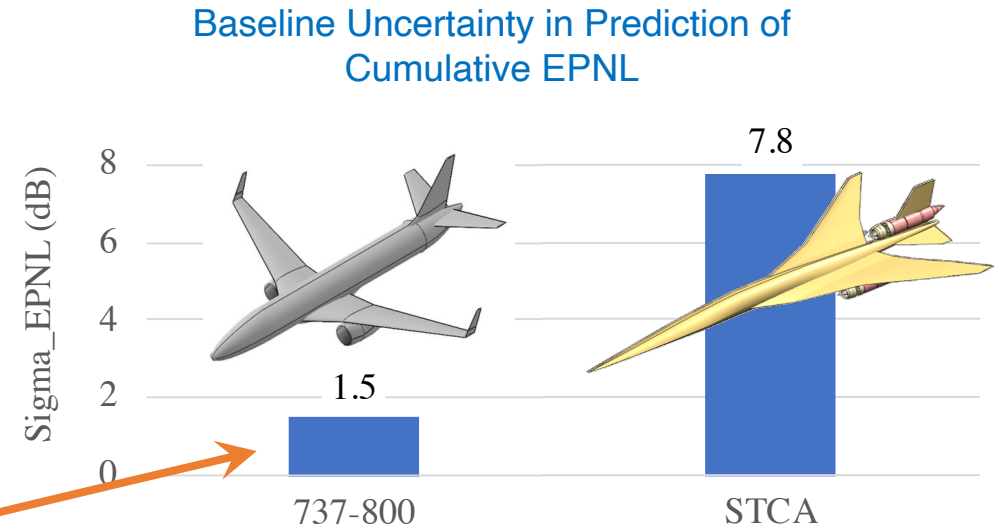
- Prediction uncertainty assessments for jet and fan components
- Input to Monte Carlo simulation of total aircraft uncertainty to baseline uncertainties

	Conventional (737-800/CFM56-7B)		Supersonic (STCA 55t-ish)	
				
	Fan	Jet	Fan	Jet
Δ_2	GEHSF rig *Exp't* ANOPP *Heidman3*	SFNT97 rig *Exp't* ANOPP *Stone2*	QSP rig *Exp't* ANOPP *Heidman3/4*	GE11, Plug20 rig *Exp't* ANOPP *SAE*

Noise Prediction Uncertainty for Total Aircraft

- PDF's of each noise component randomly sampled in 10,000-sample Monte Carlo simulation of LTO certification using system model for aircraft.
- Output is PDF of cumulative EPNL (certification metric) for Conventional and Supersonic aircraft.



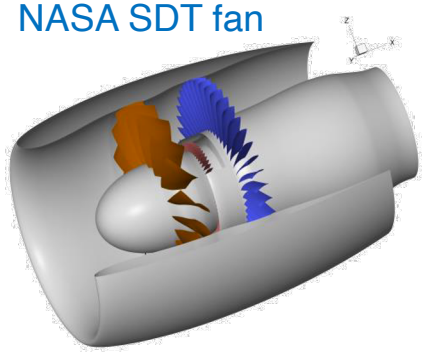


Goal of Tech Challenge: Reduce Prediction Uncertainty for Noise of Supersonic Aircraft

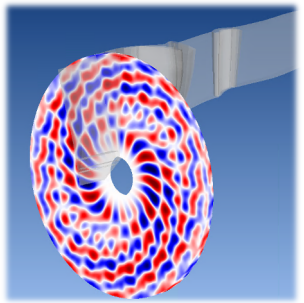
Validating PBS methods on conventional configs

- Fan: High-fidelity simulation methods validated on conventional inlet/fan data from NASA 9x15 tests.

NASA SDT fan

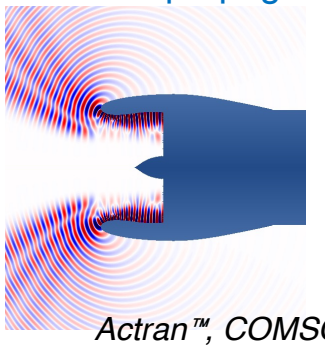


Fan noise sources



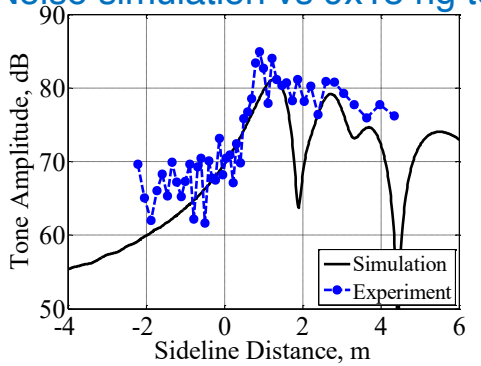
Fine™/TURBO

Noise propagation



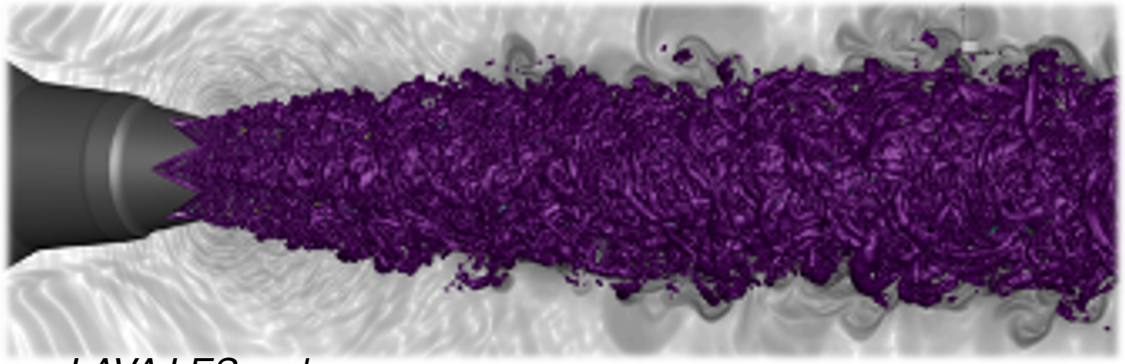
Actran™, COMSOL

Noise simulation vs 9x15 rig test



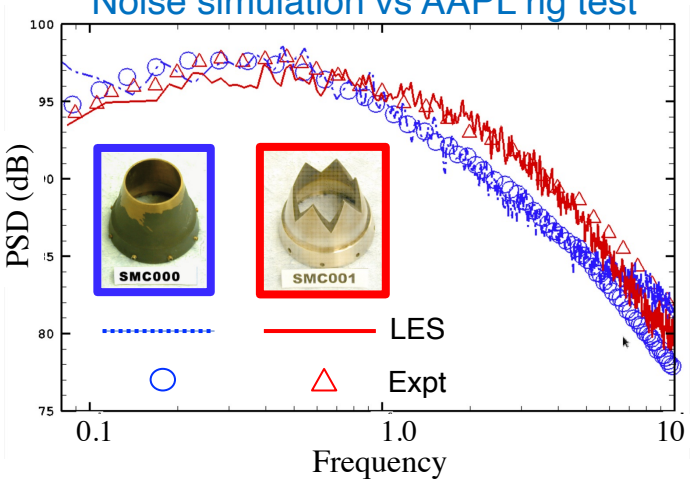
- Jet: Large Eddy Simulations validated on conventional nozzles from NASA AAPL tests.

Simulated jet flow field



LAVA LES code

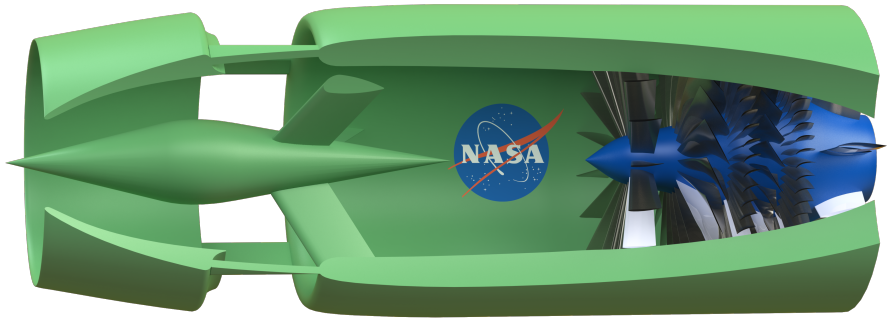
Noise simulation vs AAPL rig test

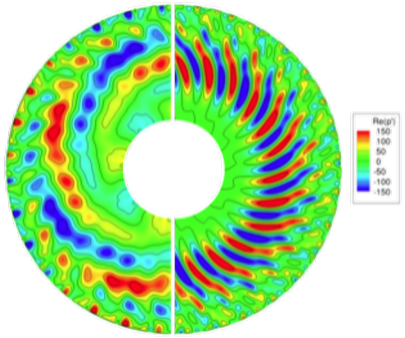


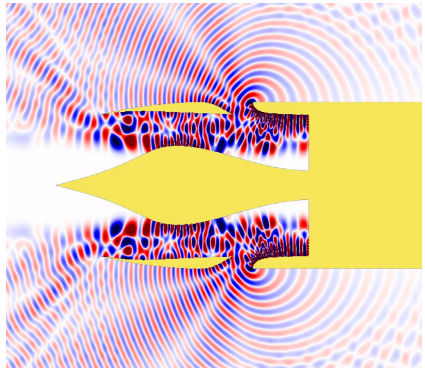
Establish Uncertainties of Simulation Methods

Developing Noise Database for Supersonic Configurations

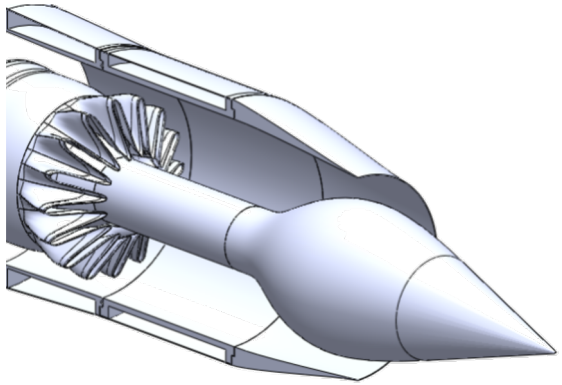
- Fan: Multi-stage fans with spike auxiliary inlets

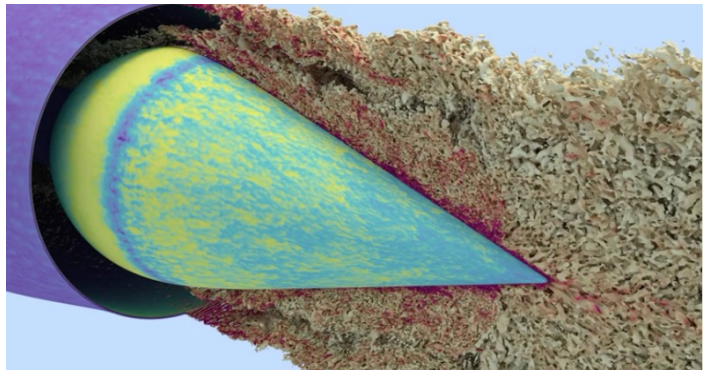






- Jet: Internally mixed, external plug nozzles





Create noise database for improved empirical noise prediction methods

Reducing Rig-to-Flight Uncertainties - Jet

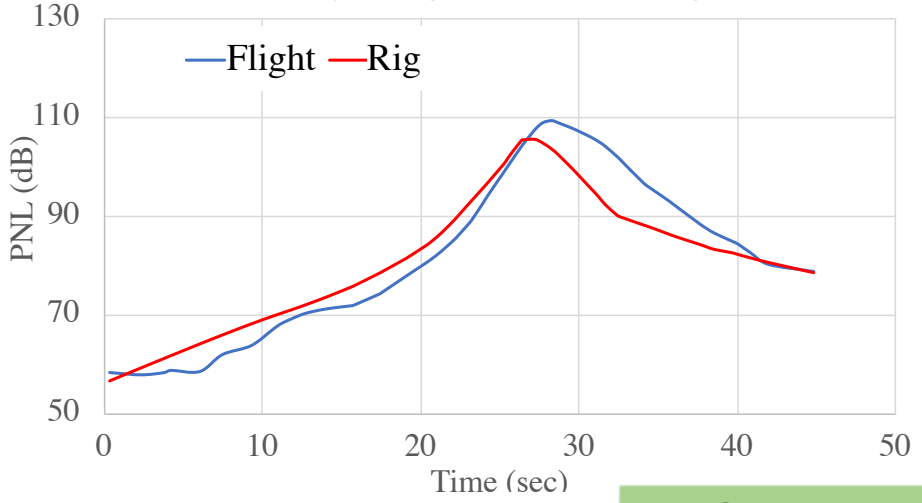
- Aircraft noise data from flight tests very scarce.

- NASA acquired noise data during 2001 Learjet noise test
  - Learjet turbojet good test case for jet noise.
  - Flight data has significant discrepancies with rig data
  - Adequate control of critical parameters not met in 2001 flight test.

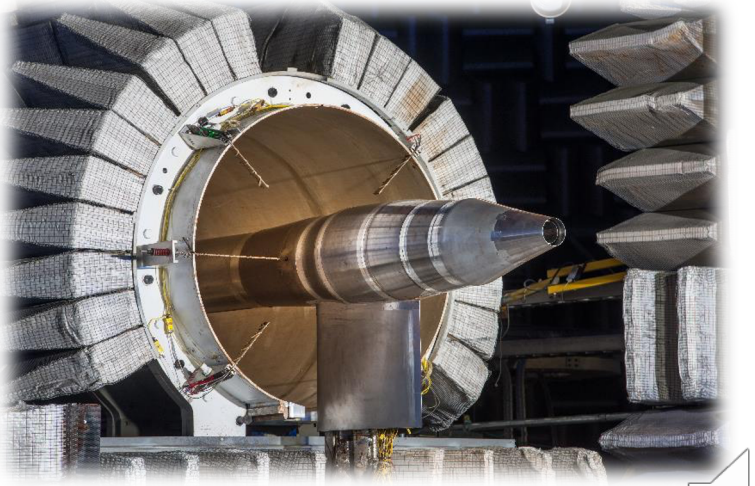
- Learjet validation flight test planned for 2022
  - Direct comparison with jet rig data.

NASA Learjet Flight 2001

Learjet Flight (2001) vs Rig



Learjet Nozzle Rig Tests



Connects Uncertainties in Noise Prediction from Simulations to Flight

LTO noise forecast for commercial supersonics

- Commercial supersonic aircraft will not be louder than current conventional fleet
  - Supersonic aircraft must blend with the fleet operating out of commercial airports
- Technology exists for supersonic aircraft noise to be acceptable
  - Does NOT require physics-defying new technology
- LTO noise is in competition with economic benefits
  - Solid engineering required to make effective compromises
  - Cutting edge prediction/design methods required!

- **Accurately** knowing the LTO noise of feasible supersonic aircraft is crucial **today**.